completely wound. The circumferential stress is the highest in the layer closest to the reel surface, and it drops rapidly within the next few layers. The stress changes from 290 MPa in the first few layers, to approximately 90 MPa in the middle layers, and then to about 150 MPa in the outer layers. The plot of radial stresses shows that the inner layers near the surface of the reel are under compression, at about –40MPa, and the middle layers have a stress level of approximately –20MPa. In the outer layers, the radial stresses are close to zero. The plot of radial stress shows a significant amount of noise, but the trend of near zero stress in the outer layers, and increasing compressive stresses in the inner layers is as expected. The "noisy" distribution of stresses shown by the FEA model are most likely due to the contribution from bending. Layers of the buffer tube closer to the reel are subjected to higher bending stress gradients as compared to the outer layers.

A graph of the circumferential strain over the length of the sheet is shown in Figure 15D. This plot shows the high spike in strain that occurs near the inner surface of the reel, and a slight variation in strain over the rest of the length. The spike in strain could be the result of an instability that occurred during the winding process. After a few layers were taken up on the reel, the layers briefly loosened, and some slack was introduced into the wound structure. The slack quickly disappeared, however, and the winding continued smoothly for the rest of the analysis. The addition of slack to the system, and the subsequent recovery could have resulted in the sharp increase in the strain.

The major difficulty with the dynamic winding simulation is maintaining stability of the winding process. Simulations were performed in which the choice of tension and velocity values, and loading rates resulted in layers coming completely off the reel. The solution also

consumes a large amount of computation time, so slowing down the velocity or the loading rate causes the analysis to take even longer to run.

A simulation was performed with a force rise time of 10.0 seconds, and with the velocity starting at 15.0 seconds and attaining its steady value by 25.0 seconds. The winding of the entire length of the sheet completed smoothly without any interruptions or instabilities. The distribution of circumferential and radial stress at 26.5 seconds is shown in Figure 16. The stresses are very similar to the fast loading rate case, except the large circumferential stress near the surface of the reel is not present. A plot of the circumferential strain, shown in Figure 17, illustrates the influence of the loading rate. The strain for the slower loading rate case is relatively smooth along the length, and does not have the large spike present in the higher loading rate case. Assuming that the faster loading rate case is not valid due to the instability, the slower case would have to be used to study the effect of winding on the stress and strain distribution. The strain for the slower case is relatively flat which suggests that there are not enough layers to cause a significant interaction between the radial compression and axial tension. This creates the need for a longer sheet of material, which would drastically increase computation time, and the possibility of instability.

The computation time for the slow loading rate case was approximately twenty hours, compared to ten for the fast case. An analysis was attempted on a longer sheet with a length of 12000.0 mm. The solution could not complete due to problems with excessive deformation after only about one wrap around the reel. Assuming a suitable set of loading conditions could be found to allow for complete winding, the solution time is still too large for the model to be practical.

Figure 18 depicts the results obtained from the second analytical model and the finite element model. As expected, due to inertia forces, fast ramping produced a wider level of "noise" in the stress curve as compared to slower ramping. Average levels of the circumferential stresses obtained from the FEA model are close to each other for fast and slower ramping. The range of stresses agrees with the the analytical solutions for the cases of $\beta = -1$ and $\beta = -2$.

A third model was developed that was suitable for studying the interaction between circumferential tension and radial compression within a reasonable amount of computation time. The model consisted of concentric rings, wrapped around a reel, which were incrementally activated into the solution with an initial tensile stress. A static equilibrium solution was obtained for each underlying layer before additional layers were added. This model also used a two dimensional, plane strain assumption for approximating the interaction of layers of buffer tubes on a reel.

Since each layer is a complete ring, quarter symmetry was used for the problem. A smaller section could have been modeled, but the quarter section makes the application of boundary conditions easier, and allows the solution to be obtained away from any end effects. The outer diameter of the reel was 240.0 mm, and the thickness of each layer was 3.0 mm. Fifty layers were modeled in order to have a significant amount of radial compression. Each layer was modeled with a single element through the thickness, and 80 elements along the length of the quarter section. Four-noded quadrilateral plane strain elements, with reduced integration, were used. The finite element mesh is shown in Figure 19A.

The nodes on the inner surface of the first layer were constrained in order to simulate the rigid surface of the reel. Symmetry conditions were applied to the horizontal and vertical